(12) UK Patent Application (19) GB (11) 2 204 136 (13) A

(43) Application published 2 Nov 1988

(21) Application No 8809483

(22) Date of filing 21 Apr 1988

(30) Priority data
(31) 302091 (32) 24 Apr 1987 (33) DD

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(51) INT CL⁴
G01C 9/06 9/20

(52) Domestic classification (Edition J):
G1N 1D5 7T1A AED
U1S 2148 G1N

(56) Documents cited
GB A 2112524 GB A 2032110 EP A2 0221016

(58) Field of search
G1N
Selected US specifications from IPC sub-classes
G01B G01C G01P

(54) A capacitative inclination sensor

(57) An inclination sensor for measuring angles and flatness over a wide range of ambient temperatures, and suitable for use in crane apparatus and conveying plant, in building construction and as an electronic spirit level, comprises a differential capacitor with a coupled evaluation device. The differential capacitor is disposed in a closed chamber 1, 2 and is formed from a pair of identical capacitor plates 3, an electrically conductive fluid 5 conductor 6 as a counter-electrode and a dielectric of a solid insulating layer 4, e.g. glass, applied to the plates 3. When the device is level the plates 3 are disposed symmetrically about a vertical axis and are shaped to have a horizontal axis if symmetry coincided with the level of fluid 5. According to the coverage of the surfaces of the capacitor plates by the fluid, the capacitance measured at the capacitor plates alters in opposite directions when the sensor is inclined, and a proportional angular change is determined therefrom.

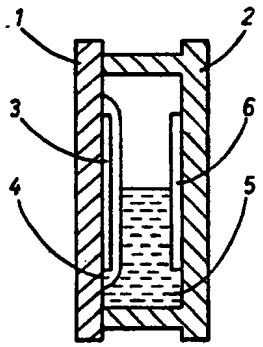

Fig 2.

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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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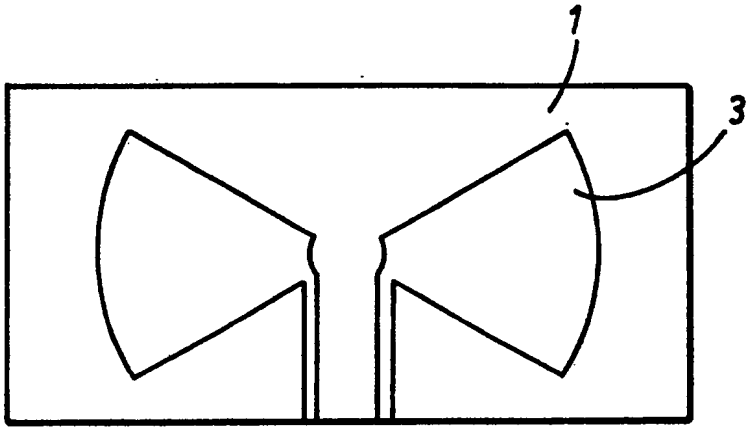

Fig 1

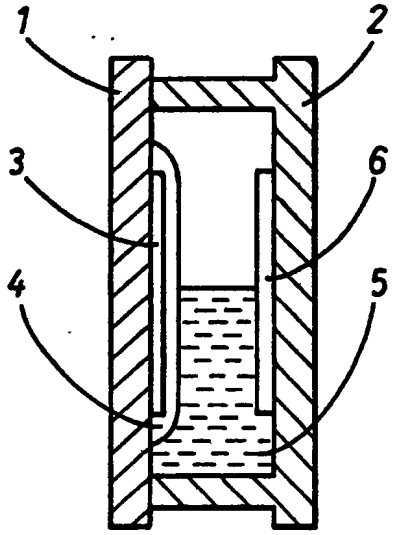

Fig 2

DESCRIPTION

A CAPACITATIVE INCLINATION SENSOR.

The invention is concerned with a capacitative inclination sensor for use in measuring angles and flatness in crane apparatus and conveying plant, in building construction, for electronic spirit levels and wherever it is necessary to make a precise measurement of angular values with respect to a plane of reference.

Arrangements for measuring angles are known which are constructed on the principle of a pendulum, the angular change of a housing part with respect to a freely suspended pendulum being imaged by way of a distance measurement. In these measurement arrangements, the disadvantages are the large mass, the large amount of space required, the mechanical expenditure and the long transient times of the pendulum. Measuring arrangements are also known which use a fluid as a gravity-sensitive element, the level of the fluid with respect to a plane of reference being sensed and converted into a measured value which is proportional to the angle of inclination. Such a measurement arrangement is described in German Offenlegungsschrift No. 25 51 798, in which the level of an electrolytic fluid is sensed by measuring the resistance between a plurality of electrodes and a resistance difference is determined.

A disadvantage of this latter arrangement is the pronounced temperature dependency of the electrolyte, so that, in the event of large deviations in ambient temperature, large measurement errors are obtained, which prohibit use of the arrangement in a wide range of ambient temperatures.

East German Patent Specification No. 226 068 describes a capacitative inclination and flatness measuring apparatus, in which a dielectric fluid having a high dielectric value is located between two capacitor plates in the form of circle sectors having a common electrode, hence forming a differential capacitor. In the event of deviations from the horizontal position of the measuring arrangement, the surfaces of the capacitor plates, which are covered with fluid, alter in opposite directions, which causes a difference in capacitance which is proportional to the change in angle.

A disadvantage of the arrangement according to East German Patent Specification No. 226 068 is the pronounced temperature dependency of the dielectric constants of the dielectric fluid, which causes large measurement errors or which allows the arrangement to be used only in a relatively small range of temperatures without causing large measurement errors. A further disadvantage is that measuring

sensitivity is limited by the need for a minimum plate spacing since, when the electrode spacing is reduced because of capillary action on the fluid setting in, measurement errors can again occur. Yet another disadvantage is the limited use of dielectric fluids at temperatures of over 50°C because of the vapour pressure, which increases the pressure inside the chamber and leads to deformation of the chamber walls, and hence once again to measurement errors.

This measuring arrangement thus requires dielectric fluids which have good wettability, low viscosity, as low a vapour pressure as possible and as small a temperature dependency as possible of the dielectric constants. These demands cannot be met in their entirety and can only be improved at the expense of the admissible measurement error and of limiting the range of temperature in which it can be used. Furthermore, in the arrangement according to East German Patent Specification No.226 068, the high technological outlay on the extremely precise, plane parallel construction of the capacitor arrangement for maintaining the plate spacing constant increases manufacturing costs.

It is an object of the present invention to provide a capacitative inclination sensor which has a high degree of measurement accuracy throughout a large

ambient temperature range with minimum measurement error, and has a space-saving construction.

According to the present invention, there is provided a capacitative inclination sensor comprising a closed chamber containing a fluid which is used as a gravity sensitive element of the sensor, a pair of segmental, electrically conductive capacitor plates located in said chamber, the plates being of identical shape and size and being so disposed as to have a horizontal axis of symmetry when the sensor is positioned horizontally, and a counter-electrode disposed in said chamber so as to form with said plates a differential capacitor, the chamber being filled with said fluid up to the level of said horizontal axis of symmetry of the capacitor plates, the capacitor plates being provided with a solid, passivation layer of a material having high electrical insulating characteristics and of uniform thickness, and said fluid being electrically conductive and forming said counter-electrode of the differential capacitor.

The passivation layer can provide a steady dielectric constant over a wide temperature range and forms the dielectric of the differential capacitor. The electrically conductive fluid may also form a common counter-electrode with a contact surface of any convenient shape.

When the inclination sensor is in the horizontal position, the fluid in the chamber reaches as far as the axis of symmetry of the capacitor plates, so that the difference in capacity measured at the differential capacitor is zero. When the sensor inclines, the surfaces of the capacitor plates covered by the electrically conductive fluid alter in opposite directions, so that the resulting difference in capacitance is proportional to the angular deviation of the inclination sensor with respect to its horizontal position. The two individual capacitances of the differential capacitor comply with the relationship

$$C = \varepsilon \cdot \frac{A}{d}, \qquad (1)$$

whereby d is the thickness of the passivation layer, ε is the dielectric constant of the passivation layer and A is the surface of the capacitor plate covered by the electrically conductive fluid.

Since the thickness of the passivation layer d has a constant value and the surface A is only dependent upon the angle of inclination of the inclination sensor with respect to its horizontal position, the symmetrical arrangement of the capacitor plates and their segmental shape produce a proportional relationship between the measured difference in capacitance and the angle of inclination. By

selecting a suitable passivation material, the dielectric constant of the passivation layer can be maintained irrespective of temperature. The only condition to be applied to the electrically conductive fluid is that of a relatively low vapour pressure, in order to prevent increasing pressure in the chamber during high temperatures causing deformation of the chamber walls or of the carrier plates for the electrodes of the differential capacitor.

The temperature dependency of the internal resistance of the electrically conductive fluid and its conductivity are negligible in the measuring arrangement according to the invention, since it is included in the measurement only as a series resistance with respect to the relatively large internal resistance of the differential capacitor.

A capacitative inclination sensor according to the invention is particularly advantageous in cases where there are large deviations in ambient temperature in a wide ambient temperature range.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:

Fig.1 is a side view of the external structure of the capacitor plates; and

Fig.2 is an end view through a section of an inclination sensor according to the present invention.

Two symmetrical segmental capacitor plates 3 are located on a supporting plate 1 and are covered with a thin layer of glass 4 which acts as a passivation layer. A hermetically closed chamber is formed using a second supporting plate 2, which is disposed at a distance from the supporting plate 1. The closed chamber contains a conductive fluid 5, whose level reaches the horizontal axis of symmetry of the two capacitor plates 3 when the inclination sensor is in its horizontal position. Together with a conductive surface 6, which is applied to the supporting plate 2, the conductive fluid 5 forms a common counter-electrode for the capacitor plates 3.

When the inclination sensor moves out of the horizontal position, the surface areas of the capacitor plates 3 covered with conductive fluid 4 change in opposite directions (i.e. one increases while the other decreases) and a difference in capacitance can be measured between the two capacitor plates 3. This difference in capacitance is proportional to the change in inclination angle of the inclination sensor from the horizontal position or with respect to the horizontal position. The extremely thin glass layer 4, whose thickness can be measured in micrometers, produces a high angular resolution when there is a large change in the

difference in capacitance per angular value. The most advantageous thickness of the glass layer 4 has proved to be in the region of 2 to 10 µm.

To use the capacitative inclination sensor, an electronic evaluation device is connected in a known way to the electrodes of the differential capacitor to measure the difference in capacitance, which is proportional to the angle of inclination, and to indicate the angular value.

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CLAIMS

1. . A capacitative inclination sensor comprising a closed chamber containing a fluid which is used as a gravity sensitive element of the sensor, a pair of segmental, electrically conductive capacitor plates located in said chamber, the plates being of identical shape and size and being so disposed as to have a horizontal axis of symmetry when the sensor is positioned horizontally, and a counter-electrode disposed in said chamber so as to form with said plates a differential capacitor, the chamber being filled with said fluid up to the level of said horizontal axis of symmetry of the capacitor plates, the capacitor plates being provided with a solid, passivation layer of a material having high electrical insulating characteristics and of uniform thickness, and said fluid being electrically conductive and forming said counter-electrode of the differential capacitor.

2. A capacitative inclination sensor as claimed in claim 1, in which the fluid in the chamber forms a common counter-electrode with a contact surface of any desired shape.

3. A capacitative inclination sensor as claimed in claim 1 or 2, in which an electronic evaluation device is connected to the electrodes of the